

# ENAM'04

## Fourth International Conference on Exotic Nuclei and Atomic Masses

*Callaway Gardens in Pine Mountain, Georgia*

**September 12-16, 2004**

### Final Report

#### **I. ENAM Conference Series**

ENAM is a triennial international conference series devoted to the physics of nuclei far from stability and radioactive ion beams (RIB). RIB science is extremely broad and diverse. It spans the gamut from nuclear structure to astrophysics, tests of fundamental laws of nature, and myriad applications. Nevertheless, it is characterized by several encompassing themes that reflect the major challenges facing modern science today, and it has deep links to many other fields.

Worldwide, the study of exotic nuclei is in rapid advance. Major projects are planned or already under way in Europe, North America, and Japan. The field is vital and intensely active. With the large number of radioactive ion beam facilities that are operating, under construction, and proposed, ENAM is a unique forum to discuss the exciting developments in the field, including experimental discoveries, theoretical modeling, technological advances, and applications.

ENAM'04 can trace its origins to the 1950s and 1960s with the Atomic Mass and Fundamental Constants (AMCO) and the Nuclei Far From Stability (NFFS) series of conferences. Held jointly in 1992, the conferences officially merged in 1995 in Arles, France where the First International Conference on Exotic Nuclei and Atomic Masses was held. Since that beginning, the triennial conference has been held at Bellaire, Michigan (1998) and Hämeenlinna, Finland (2001). The Fourth Conference was held at Callaway Gardens in Pine Mountain, Georgia. The timing of the meeting was excellent. The recent Nuclear Physics Long Range Plan has identified the Rare Isotope Accelerator as the highest priority for new construction in nuclear physics for the United States. For the RIA community in the USA, and for the RIB community worldwide, ENAM was the single most important meeting.

#### **II. ENAM'04 Organizers and Conference Site**

The Scientific Chair of the meeting was Witek Nazarewicz from the University of Tennessee. Our International Advisory Committee (27 members) was quite diverse and represented the countries and institutions, which are prominent in the field. Many members have long histories with previous AMCO, NFFS, and ENAM conferences, and are recognized as the world's experts.

The Chair of the local organizing committee was Carl Gross from the Oak Ridge National Laboratory. Other members of the committee were: C. Baktash (ORNL), D.W. Bardayan (ORNL), J.C. Batchelder (UNIRIB), J.R. Beene (ORNL), C. R. Bingham (UT),

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ENAM'04 was held September 12-16, 2004 at Callaway Gardens, Pine Mountain, Georgia. The conference site has been chosen very carefully. It is the tradition of the conference to be located in a fairly remote area surrounded by natural beauty, and we feel the selection of Callaway Gardens as our venue fulfilled this tradition admirably. Lodging and meals were centrally located to allow participants the opportunity for interaction. The meeting facility of Callaway Gardens was the Southern Pine Conference Center, which opened in Fall 2002. This modern facility was designed to blend in well with the surroundings and was built in an environmentally sound manner. Location and infrastructure maximized the communication: all participants lived in a close environment, ate together, and participated in joint social activities. By choosing a location of which is in itself a tourist destination, we avoided the need to have a specific companion program and an afternoon lost to the "conference excursion". This allowed us to maximize the science content of the program and still provide a relaxing atmosphere with 2.5 hours free time most afternoons and concerts on Sunday and Wednesday nights.

### **III. Participation**

The conference received an initial registration of more than 350 possible participants. Of these, 280 attended representing 23 countries on 4 continents. The United States had the largest contingent with 45% of the participants. The participants came from the following countries: Belgium (6), Bulgaria (1), Brazil (2), Canada (11), Croatia (2), Denmark (2), Finland (12), France (14), Germany (23), India (2), Israel (2), Italy (7), Japan (28), Mexico (3), Netherlands (2), Poland (8), Russia (5), Spain (3), Sweden (2), Switzerland (8), Ukraine (2), United Kingdom (9), United States (126). The complete list of participants can be found at <https://www.phy.ornl.gov/enam04/participants.pdf>.

In order to ensure good participation from as many countries as possible, we registered the conference with the U.S. Department of State through the National Academy of Sciences. The conference website provided links to official websites which provided detailed instructions on the visa request process and deadlines. We provided monthly participant lists (starting in April) and contacted the Department of State periodically with regard to participants who had not yet received their visas. According to our records only two participants did not attend due to visa difficulties. One participant did not wish to surrender his passport for the necessary length of time required and one had received a late date for his interview, which suggests that he did not initiate the process within the required 90 days. While others had some difficulties, all problems were resolved in time for the conference.

A new DOE requirement caused us to gather birth information from our participants. The age of the participants spanned 6 decades while the average participant was 42 years old. There were 44 students or more than 15% of the total. In addition, 42 participants were female or 15% of the total.

## **IV. Sponsors and Support**

### **Institutional Supporters:**

- U.S. Department of Energy
- National Science Foundation
- Oak Ridge National Laboratory
- Joint Institute for Heavy Ion Research
- Physics Division, Oak Ridge National Laboratory
- International Union of Pure and Applied Physics
- Office of Research, University of Tennessee
- Oak Ridge Associated Universities
- University Radioactive Ion Beam Consortium (UNIRIB)
- Department of Physics and Astronomy, University of Tennessee
- Department of Physics and Astronomy, Vanderbilt University

### **Business Supporters**

- X-ray Instrumentation Associates
- European Physical Journal A - Springer
- IOP - Journal of Physics G
- Leybold Vacuum
- CAEN S.p.A
- WIENER Plein & Baus, USA
- Saint-Gobain Crystals (Bicron and Crismatec products)
- Canberra
- Physical Review Letters and Physical Review C
- RIS (Custom electronics)
- Quantar Technology Incorporated
- MDC Vacuum Products Corp/Insulator Seal

Financial support was provided to 67 participants. Several more were offered support but for various reasons, could not take advantage of the offers. Of the 67, 11 U.S. students and 15 non-U.S. students were offered support ranging from waived conference fees to complete local support. In addition, all students received a reduction in conference fees worth \$180.00. Nine researchers whose home institutions are in low income countries (Russia, Ukraine, India) received support as did others from lower middle income countries (Poland, Croatia, Brazil). In addition, 20 postdoctoral researchers received support, 11 of which were from U.S. institutions. Note that the majority of US students and postdocs who applied for support on time, received support for all local expenses (conference fees, lodging, and meals). Only local expenses were covered by conference support funds.

## V. Program

The science program was excellent covering topics of atomic masses, nuclear structure of exotic nuclei, reactions with radioactive ion beams, clusters and nuclear driplines, nuclear astrophysics, heavy elements, nuclear fission, and production of radioactive ion beams and applications. The program consisted of over 33 hours and 45 minutes of oral presentations and more than 160 poster presentations over two sessions. There were no parallel sessions and ample time was provided for collaborative discussions as well as relaxation in the gardens.

The conference received more than 280 abstracts (including invited presentations) from which 130 oral presentations were selected; 43 of which were 5-minute oral advertisements (oral-posters) for their posters.

The talks (<http://www.phy.ornl.gov/workshops/enam04/orals-alphab.html>) were broken down into:

- 36 invited talks of 25 or 30 minutes
- 48 contributed talks of 15 or 20 minutes
- 1 contributed talk of 25 minutes
- 43 oral-posters of 5 minutes
- 2 welcome/summary

As a service to our community, oral presentations from the conference have been posted on the web: <https://www.phy.ornl.gov/enam04/WebTalks/>. The abstracts of the 119 poster contributions can be found at <http://www.phy.ornl.gov/workshops/enam04/Posters/>.

Of the 36 invited talks, three were given by women physicists; five women physicists presented contributed talks; eight presented oral-posters; and 15 had posters. Thus, 12.5% of the oral presentations were by women physicists.

This was the first ENAM, which used the oral-poster format. In these presentations the contributor received 4-5 minutes (3 slides) to advertise their poster. Discussion was delayed to the poster session. We received extremely positive feedback with this addition to the program. In most cases, the "bottom-line" concept of oral-posters worked beautifully. A summary of the feedback includes:

- Great idea - a lot of people, particularly young researchers and students, received exposure and a good experience.
- The talks were short enough that you received just the facts with little fluff.
- Great tool for students to compress their message in a nutshell.
- It energized the sessions after a few longer talks. The constantly changing subjects and/or speakers held our interest.

We made a special effort to increase the participation of students and young researchers at the meeting. Many student and postdoc contributions were selected as contributed talks and poster presentations. In addition, on Monday and Tuesday we organized informal student/postdoc discussion sessions in the evenings. During these well-attended sessions, the leaders in the field led the discussion and answered questions about science and related topics (perspectives in nuclear physics, job prospects, research in general, life in academia, and the role of a scientific mentor). These informal sessions with young researchers were very well received. They should definitely be continued in the future.

The scientific level of presentations was very high. The level of poster sessions was also very high, both scientifically and technically. We received a number of enthusiastic comments from participants about the science presented:

- "I am writing to say how much I enjoyed ENAM04 and its outstanding scientific & social content and organization." (Peter Butler, Director of ISOLDE, CERN)
- "The program was excellent and the location worked very well. I know how much effort has to be put in to run a successful meeting, so I am sure the whole community really appreciates all the efforts you have made." (Alan Shotter, Director of TRIUMF, Canada)
- "Thanks for a great conference. It was the best ENAM (conference that I have been to and I have been to every one since my first in 1976." (Ed Zganjar, LSU)

## **VI. Organization details**

Almost all oral presentations **were done electronically** and uploaded into a special talk database. Of the 130 oral presentations, only 3 required the use of an overhead projector. We limited ourselves to using two formats (PowerPoint and pdf) with the oral-posters required to use pdf in order to minimize the urge to use unnecessary animations. A few presenters required movie formats to better illustrate animations (our upload software did not allow this possibility). The majority of people used the conference-supplied computers running Windows XP and MacOSX 10.3. We received many compliments on the smooth organization and transition of the oral presentations. A master schedule page contained links, which automatically started the PowerPoint or Acrobat presentation. Most of the presentations were uploaded in advance and served on the local machines.

**Timing** in the sessions was governed by a computer program, which sounded a warning tone with approximately 10% of the time remaining. Note that the tone was specifically chosen to be heard but not startle. Such timing control was necessary due to the wide range of times in each session. Discussion time was also monitored and warning tones were also issued once time had elapsed.

We devised a **grading database** for the abstracts. The International Advisory Committee could download and read each abstract they were assigned and then provided a grade of oral (3 points), oral/poster (2), poster (1), and reject (-1). In addition, a small space was provided for a very brief comment or explanation. In this way, each abstract could be

easily reviewed and all grades summarized. This system worked well and permitted a fairly rapid condensation of the grades to the type of presentation offered. We are happy to report that only three abstracts were rejected outright and very few refused an oral presentation including the new oral-poster format.

**Posters** required several rooms and the purchase of more than 130 individual easels. While easels could be rented in Atlanta, the costs were such that it was cheaper to purchase easels ourselves and provide foamcore backing. Alphabetical lists and room assignments were provided to participants in advance of the meeting.

The **conference website** (<http://www.phy.ornl.gov/workshops/enam04/>) was used extensively to communicate to all participants and we received some praise for the amount of information that was provided. Registration took place in several steps as more information was needed as people finalized their participation and travel plans. For example, only registrant information was required prior to submitting an abstract (Acrobat format only - 1 page). Upon acceptance of the abstract, the participant was then able to provide lodging and travel information. There was a separate form to indicate special needs. Note that we had approximately 20 people who identified a special need; a few more did so at the conference. At the top of the website, a dated list of notices was presented to inform people of changes, approaching deadlines, and to provide other links such as the schedule, poster assignments, etc. Important information was also conveyed through mass mailings only to those who had registered or who needed the announcement (e.g. speaker instructions were not sent to poster presenters).

A **computer room** was provided as well as **wireless** throughout the facility. While many people bring their own laptop to conferences, many still expect a large room with many computers available for their use. We provided only 6 such computers and 1 of these died during the conference. We did provide numerous ports for their own non-wireless computers. A laser printer (B/W) was also provided.

## VII. Proceedings

In order to more widely disseminate information gathered at this conference, the European Physical Journal A Direct of Springer Publishing will publish the proceedings. The advantages of this choice are:

- All contributions will be peer-reviewed.
- All contributions, including posters, are eligible for inclusion into the proceedings.
- Participants will receive a **printed volume** with all contributions
- All contributions, which pass the peer-review, will be published on-line within 3 weeks of manuscript delivery to the publisher and **will receive a journal citation.**
- Contributions submitted after the deadline will not delay prompt publishing of other contributions.
- A deadline, January 15, 2005, to close the proceedings volume was given.



The manuscripts should be available online three weeks after they are sent to EPJ A Direct. We hope to have the initial contributions on-line around January 1, 2005. The printed version is expected to be mailed to all participants in Summer 2005. The details related to the format of ENAM'04 proceedings can be found at <http://www.phy.ornl.gov/workshops/enam04/Proceedings/>

## **K. DESCRIPTION/ABSTRACT**

The conference can trace its origins to the 1950s and 1960s with the Atomic Mass and Fundamental Constants (AMCO) and the Nuclei Far From Stability (NFFS) series of conferences. Held jointly in 1992, the conferences officially merged in 1995 and the fourth conference was held at Callaway Gardens in Pine Mountain, GA and was organized by the Physics Division at Oak Ridge National Laboratory. The conference covered a broad list of topics consisting of a series of invited and contributed presentation highlighting recent research in the following fields:

- Atomic masses, nuclear moments, and nuclear radii
- Forms of radioactivity
- Nuclear structure, nuclei at the drip lines, cluster phenomena
- Reactions with radioactive ion beams
- Nuclear astrophysics
- Fundamental symmetries and interactions
- Heaviest elements and fission
- Radioactive ion beam production and experimental developments
- Applications of exotic nuclei

# Concluding Remarks of the ENAM'04 Conference

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**Abstract.** In this talk a summary of the program and scientific highlights of the ENAM2004 conference will be presented.

**PACS.** 20 Nuclear Physics

## 1 Introduction

To start, I would like to congratulate Witek Nazarewicz, Carl Gross, and the team from Oak Ridge for putting together and running this magnificent conference. Of course they could not have done this without the active role of participants of the conference, who are to be thanked as well. The conference program has been really outstanding and extremely interesting, and has demonstrated the scientific impact of the field in an important way. I am in this situation because it has been a tradition of the ENAM conferences that the chairman of the previous conference delivers the summary talk. I am sure Witek Nazarewicz is looking forward to this honorable duty in four years time in Poland when our colleagues will be organizing the next conference. There also seems to be another tradition not decided by us, namely the stormy weather during one of the days of the conference. I remember, last time in Finland, we also had a major thunderstorm during the last session of the conference, and this tradition seems to be following us everywhere.

The progress in our field since the last ENAM conference has been fast and noticeable. I think that this progress is speeding up with these conferences. One way to observe the progress is simply to look at the numbers and the statistics of this conference. We had 280 participants, 84 oral talks, 43 oral poster talks, and 162 posters. The oral poster presentations, a new feature of ENAM, was a very good idea indeed. The presentations were very informative and provided an opportunity for many more participants to actually present their work. The presentations have been of very high quality. Electronic presentations really provide an extremely efficient tool for bringing the information to the audience. Also, the posters have been of a very high quality, and I have seen that the discussions have been very lively in the poster sessions. In particular, the younger participants have been able to communicate their results and interact with the rest of the conference participants.

The conference covered basically all of its traditional areas. I could not help noticing that the community working in nuclear spectroscopy, especially in in-beam spectroscopy, has been directing its interests toward nuclei far from stability and contributing in an important way to this conference. I estimated that about 30 per cent of the conference contributions have come from the field of in-beam spectroscopy, providing a nice complementary addition to the field.

The development in the field has been driven by a number of advances, but not least by the new facilities that are being planned and constructed and taken into operation. In particular in this conference, the MSU Cyclotron Laboratory and RIKEN have shown up in a very strong way without forgetting other facilities like HRIBF, REX-ISOLDE, TRIUMF, and many others. One typical feature in this field is that much of the research we do, is done in large collaborations and this also, I think, is an important factor. Collaborations are spread across the seas and we seem to have the ability to do our research today in a nearly optimal way with regard to our the resources and infrastructure.

In the following, I will discuss the conference content itself. As mentioned, we had close to 250 presentations, and therefore it will be impossible to give a comprehensive summary in a short time. What I am reviewing here is a summary which is, of course, strongly biased, being based on my personal impressions and taste, as well as on my knowledge of different areas of this field. I did attend all sessions; I learned a lot, and, in fact, you will see throughout this presentation that I will try to bring up some of the highlights of this conference which struck me the most. The progress has been very strong and powered by the constant development of the equipment and computing power. Several of the new methods that were discussed at the previous ENAM conference are now in full use to produce physics.

## 2 Masses

The conference started traditionally with the session on atomic masses. We are now in a fortunate situation that the new atomic mass tables were introduced just prior to this conference, representing a collection of the best atomic mass values. There are two components in the tables, stable and radioactive atomic masses, as discussed by Aaldert Wapstra. As compared to the old table, the new table has a large amount of new information.

David Lunney gave a beautiful presentation on the masses, emphasizing the fast progress in this field over the last couple of years. There are many new developments in experimental techniques that have led to this. For example, the ion traps with a new feature, e.g., to introduce the ions into a trap in an efficient and fast way has opened up a possibility to develop a major new tool in mass measurements for radioactive isotopes. Relative precision can typically reach the lower end of the  $10^{-8}$  range for nuclides with half-lives less than 100 ms. Several examples, such as  $^{22}\text{Mg}$ ,  $^{22,33,34}\text{Ar}$ ,  $^{68}\text{Se}$ ,  $^{72}\text{Kr}$ , and  $^{74}\text{Rb}$ , mainly from the ISOLTRAP group but also from the Canadian Penning Trap group at Argonne, were presented and discussed at this conference. Also, a new Penning trap at Jyväskylä has started to work, and the very first results on masses of refractory fission products were presented at this conference by Ari Jokinen. There was a remarkable result reported by Cyril Bachelet concerning the mass of  $^{11}\text{Li}$ , a very exotic short-lived nucleus, whose mass was measured by the MISTRAL spectrometer to a precision of 5 keV. The actual mass-measurement facility, one could say, is the experimental storage ring of GSI, which has recently produced a large number of new masses for neutron-rich nuclei. By its nature, this technique is universal and will, in the future, be a very important technology for mass measurements of very exotic nuclei. We also heard from GANIL, where a large number of new masses near the neutron drip line at  $N \sim 20$  were reported by Herve Savajols. Many other techniques were reported and discussed. One of them applied accelerated radioactive ions and the household appliances at HRIBF to measure masses of exotic copper and germanium isotopes close to doubly magic  $^{78}\text{Ni}$ .

In theory, the development of mean-field theories, providing a global approach to connect masses to effective interactions, has provided important tools for mass predictions, for example, in astrophysics. In the future, there is also a need to address the local structure effects in binding energies to understand the physics behind the fine structures. Stephane Gorieli presented his overview talk giving a very nice description of the current situation on the different theories for the mass calculations. As he stated, the future challenge lies in a unified description of masses and other nuclear properties. One example discussed was the evolution of the  $N=82$  shell-gap as a function of the proton number. It was shown that different models deviate significantly from each other. It is of significant interest to extend the experimental measurements down towards the lighter elements, as reported by a recent experiment

at ISOLDE where the mass of  $^{130}\text{Ag}$  had been deduced from a beta end-point measurement.

Because mass-measurement techniques have advanced in a major way in recent years, one may ask the question: why and where do we need these new accurate masses? In fact, there are many requirements for high precision. At this conference we have heard about testing the validity of the Standard Model in various ways. In experiments on superallowed Fermi-decays, a very accurate measurement of mass differences or decay energies, e.g. much better than one keV, is required. I think John Hardy was asking for a 100 electron volt or better precision. This is, of course, a very challenging, but not an impossible task, for example, for Penning traps. Typically, in some cases in astrophysics, especially when resonant capture reactions are studied, the accuracies have to be well below 10 keV. Nuclear structure studies require an accuracy somewhere around 100 keV or better. If one looks globally over the distant wings of the nuclidic mass surface, something like a half of an MeV is still acceptable and useful.

## 3 Moments and Radii

From masses we move on to moments and radii. Spin-polarized radioactive beams at high and low energy, as reported by ISOLDE and GANIL, have become important tools in structure studies of nuclei close to  $N=8$ , 20, and 28, as described in the presentations of Gerda Neyens and Magdalena Kowalska. Many important studies close to the magic neutron numbers far from stability on the neutron-rich side have been made by these groups. There has been major progress in studies of moments and radii of refractory neutron-rich nuclei. They have become available, as reported by Jon Billowes, for collinear laser spectroscopy, mainly thanks to the recently developed cooling and bunching techniques for short-lived radioactive ions. There is also resonant laser ion source spectroscopy that has been applied to study the coexistence of shapes in lead nuclei at ISOLDE. Two outstanding results were reported at this conference, namely the accurate measurements of the charge radii of  $^6\text{He}$  and  $^9\text{Li}$  by Peter Mueller and Wilfried Nörtershäuser, respectively. These experiments will eventually lead the way for future measurements in the same quantities for two important halo nuclei,  $^8\text{He}$  and  $^{11}\text{Li}$ . There were, in addition, several experimental results on studies of matter radii and matter distributions of exotic nuclei done by various experimental setups at RIKEN, GSI, GANIL, and MSU. Also, we heard about the g-factor measurements with neutron-rich radioactive beams as reported, for example, by the Oak Ridge and Munich groups. It is clear that in the future we need systematic studies over a broad range in proton and neutron numbers. In particular, I would like to express a wish to get radii in the island of inversion region near  $N=20$ . There are measurements by the ISOLDE group on the neutron-rich magnesium isotopes up to  $^{28}\text{Mg}$ ; but now the challenge is to go further.

One of the outstanding results presented at this conference was the measurement of the quadrupole moment

of  $^{11}\text{Li}$ . The accuracy for the experimental ratio of the  $^{11}\text{Li}$  to  $^9\text{Li}$  quadrupole moment has been improved significantly over the years. The quadrupole moment of  $^{11}\text{Li}$  is 10 percent higher than the one of  $^9\text{Li}$ , which indicates that halo neutrons must partially be in the  $d_{5/2}$  orbital, a result that confirms the recent reaction experiment at GSI.

## 4 Radioactivity

Hubert Grawe gave a nice overview of the nuclear structure changes along the  $N=50$  neutron shell, starting from the  $^{78}\text{Ni}$  region up to  $^{100}\text{Sn}$ . He pointed out the importance of  $l=2$  core polarization as a mechanism leading to isomerism and, in general, the important role of the monopole interaction in the structures of these nuclei.

Radioactivity studies continue to be a rich source of information on single-particle states near the magic numbers far from stability. For example, Paul Mantica's overview talk discussed a number of experiments that have been done on the beta decays of aluminum and sodium nuclei, mapping the levels and spins on both sides of the  $N=20$  magic neutron number. Another presentation related to these nuclei, more specifically to the lifetime measurements of their excited states, was given by Henryk Mach.

Isomeric decays, as discussed by Robert Grzywacz, were demonstrated as an important spectroscopic tool at the previous ENAM2001 conference. They have been effectively used to probe nuclear structures and states of medium and high spin very far from stability. At this conference, Ivan Mukha reported the discovery of the highest spin beta-decaying isomer discovered so far,  $^{94}\text{Ag}$ . The story is just beginning, and it seems to me that this one isomer will, in the future, provide us a rich laboratory of nuclear structure and radioactive decay studies.

Experimental activity in the proton decay studies has somewhat diminished due to the natural reason that there are fewer and fewer new cases to be studied. It was satisfying to observe that the theory effort in the field of proton and two-proton decay is substantial and extremely important, as reported by Cary Davids, Alexander Volya, and Jimmy Rotureau and co-workers. For experiments, there are new techniques which provide a complementary approach to get additional information on the excited states preceding the proton decay, as discussed by Andrew Robinson. Two-proton radioactivity was reviewed by Marek Pfutzner. In fact, a few weeks after the previous ENAM conference the first evidence for two-proton radioactivity of  $^{45}\text{Fe}$  was observed at GANIL and at GSI. It seems that there are other interesting candidates for true diproton (or  $^2\text{He}$ ) radioactivity which still remain to be uncovered. In this connection, we have already heard about a new two-proton emitter,  $^{54}\text{Zn}$ , presented by Bertram Blank. To unravel the decay mechanism, one really needs new detection systems for energy and angular correlation measurements.

When the experiments advance very far from stability, it remains important to obtain information on gross decay properties, but as a second step, we will have to aim

at high-resolution, high-sensitivity experiments to uncover the increasing complexity of radioactive decays.

## 5 Clusters and Drip Line

There were two interesting sessions on drip-line nuclei, especially on the role of clusters in nuclear structure that was reviewed very nicely by Y. Kanada-En'yo. She showed convincingly that clustering really plays an essential role in structures of unstable light nuclei as well as in some stable nuclei. In fact, even  $^{12}\text{C}$ , in the framework of cluster physics, stays in the news both from a theoretical as well as from an experimental point of view. Recently, there has been plenty of new information reported at the conference on the states of  $^{12}\text{C}$  at about 10 MeV excitation energy. This new information will also have an impact on the triple-alpha process leading to the formation of carbon in stars.

The clusters and the mean field do coexist and both need to be considered at the same time to understand the structures observed in light nuclei. A specific problem concerning the concept of a tetra neutron was discussed both in the experimental talk of Miguel Marques and the theoretical presentation of Steven Pieper. It seems that some more work is needed since our current rational understanding of nuclear force and nuclear interaction does not allow a bound tetra neutron.

It was interesting to hear from Michael Thoennessen that there are still about 200 nuclei to be discovered near the proton drip line. Two of these were presented by Andreas Stolz, who presented evidence of new nuclei  $^{62}\text{Ge}$  and  $^{64}\text{Se}$ . There has been a considerable amount of work done at Jyväskylä on alpha decays near the proton drip line, as reported by Juha Uusitalo.

## 6 Nuclear Structure and Spectroscopy

The main general subject of the conference, nuclear structure and spectroscopy, covered about 30 percent of the program. It included several interesting presentations. The main theme currently is the study of neutron-rich nuclei at and near the classical closed neutron shells, but far from stability. There are several different experimental approaches that were presented; the accelerated radioactive ion beam experiments were reported mainly by teams from REX-ISOLDE at CERN and the HRIBF at Oak Ridge. In both, Coulomb excitation and transfer reactions have been employed in experiments near  $N=20$ , 50, and 82. There were also a number of experimental results reported from RIKEN and MSU using the fragmentation technique. Since fragmentation is a universal production method, it allows studies of many exotic nuclei simultaneously and with high sensitivity, but it lacks the high accuracy of in-beam spectroscopy. A continuing important role of the network of stable beam facilities was demonstrated by several contributions from Argonne, Legnaro, Jyväskylä, and elsewhere. The successful future of this

field calls for a constant development of tracking methods for gamma rays and charged particles.

I will briefly highlight some examples of studies presented at the conference. The first results employing Coulomb excitation of n-rich Mg isotopes from REX-ISOLDE were reported by Heiko Scheit. The  $B(E2)$  value observed for  $^{30}\text{Mg}$  was found to be in some discrepancy with the values derived earlier from the high-energy experiments at GANIL and MSU. The newest data, presented by Robert Varner and David Radford, yielded  $B(E2)$  values for Sn and Te isotopes. The experimental values for Sn at  $N=80$ , 82, and 84 are reproduced rather nicely by the theory. Also, we heard about an interesting experiment at RIKEN on  $^{30}\text{Ne}$ , which had been done with a beam intensity of only 0.3 ions/s. It detected, for the first time, the first  $2^+$  excited state at 790 keV in  $^{30}\text{Ne}$ , which is very similar to  $^{32}\text{Mg}$ . It seems to have, if based on the energy argument alone, a similar collectivity as that of  $^{32}\text{Mg}$ . Level lifetime measurements employing the recoil shadow technique, reported by Hiro Sakurai, also from RIKEN, was very interesting. The anomalously small  $B(E2)$  value for  $^{16}\text{C}$  suggests a strong contribution of neutron matter to this excitation. This was also discussed by James Vary, who presented theoretical calculations based on the no-core shell model that reproduced the experimental value very nicely.

There was an interesting presentation by Janne Pakarinen, which concerned the probing of the famous  $0^+$  state structures in  $^{186}\text{Pb}$  studied at Jyväskylä using the recoil decay tagging. The group had identified a new rotational band based on one of the excited  $0^+$  states. More work is needed here to clarify the picture, but there has been a lot of progress in this area.

We heard of several new results from Legnaro, as reported by Andres Gadea. The PRISMA spectrometer, coupled with the CLARA Ge-array, is now in full operation and is going to provide us with a large amount of spectroscopic information on neutron-rich nuclei via transfer reactions in the coming years. Frank Becker reported on a larger number of results from the GSI RISING setup. For example, they have measured the first  $B(E2)$  values for neutron-rich  $^{54-58}\text{Cr}$  nuclei.

This conference has convincingly shown that we have made many significant developments in nuclear structure theory. Several of these were discussed in review talks, such as the ab-initio no-core shell model overview talk of James Vary. No-core shell-model calculations employing realistic two- and three-body interactions were also discussed by Peter Navrátil. Coupled-cluster calculations were extensively reviewed by Piotr Piecuch, and microscopic models for exotic nuclei were treated in an extensive way by Michael Bender. Wojtek Satula discussed a special treatment of the isospin degree of freedom in nuclear structure calculations. It seems that any given theory framework is becoming increasingly tested against many observables at the same time, including binding energies, excited states, as well as nuclear bulk properties. It is obvious that the predictive power of theories has been significantly improved, which will eventually lead the way

to new and better formulated physics searches far from stability.

## 7 Heavy Elements

At the time of the ENAM2001 conference, the heaviest element observed was the one with  $Z = 112$ , and then we had this mysterious  $Z=118$  result. Since those days, the community has become extremely active, and heavy element research has gained new momentum in many ways. For example, during the last year or two, two new elements were named,  $Z=110$  as Darmstadtium, and  $Z=111$  as Roentgenium. Several new results were discussed by Dieter Ackermann, Vladimir Utyonkov, and Paul Greenlees. The Berkeley activity in this field is back on track, and the LISE spectrometer at GANIL has entered the field as another new player. There were some really exciting new results from RIKEN, namely the discovery of a new element  $^{278}113$  by Kosuke Morita and his team. This result was reported by Dieter Ackermann. It was a pity that there was no Japanese presentation of this beautiful result. In-beam spectroscopy studies of transfermium elements have been pushed to more new nuclei around  $^{252}\text{No}$  at Jyväskylä and Argonne.

We had an interesting presentation by Heinz Gaeggeler on the chemistry of the superheavy elements. He presented exciting results on the chemistry of the element 112 done at GSI and on the chemistry of Dubnium, which was produced as a decay product in the decay chain of element 115 observed in Dubna. It is important that chemists participate in the research, because they will be very helpful in assigning the  $Z$  of the new elements.

If we look at the upper corner of the nuclear chart, it has many interesting new features. There is the so-called Nobelium region which is actively researched by the Jyväskylä and Argonne groups for excited and microscopic structures. We have several new elements and isotopes produced in cold fusion reactions at GSI and at RIKEN and, finally, more than 30 new isotopes, all produced at Dubna in hot fusion reactions. The decay chains of the latter nuclides end up in unknown isotopes. Connecting these chains to the known upper part of the nuclear chart will be a challenge for future studies in this field.

## 8 Reactions

Reactions were discussed in penetrating ways. The field is developing very rapidly, although difficulties related to the beam quality, the energy, and angular resolution need constant attention. There were several reports on low-energy radioactive ion beam experiments concerning the fusion reactions of neutron-rich nuclei. The proof for the expected enhancement of fusion was shown by Walter Loveland for the  $^{132}\text{Sn} + ^{64}\text{Ni}$  reaction at sub-barrier energies. The first spectroscopy results by transfer reactions at the new VAMOS facility at SPIRAL were presented by Wilton

Catford. Several high-energy experiments were described. Knock-out reactions used for extracting spectroscopy factors along the isotones were described by Alexandra Gade of MSU with an intriguing difference in valence neutron orbital occupation observed between  $^{22}\text{O}$  and  $^{32}\text{Ar}$ . Deeply bound states in  $^{32}\text{Ar}$  possess a very small reduction factor compared to loosely bound  $^{22}\text{O}$ .

Also, scattering experiments used to extract radii and halos of drip-line nuclei were presented by Wolfgang Mitig and several other contributions. A special technique relying on scattering of radioactive beams from a polarized hydrogen target was introduced by Hide Sakai who demonstrated the sensitivity of the reaction in probing the radial extension of the spin-orbit part of the nuclear potential.

## 9 Nuclear Astrophysics

Nuclear astrophysics was presented in a very lively presentation by Art Champagne. We often discuss the importance of nuclear physics in astrophysics, and I just want to agree with the statement of Hendrik Schatz that the role of nuclear physics should not be underestimated in astrophysics. Several key reaction rates continue to be of interest in this field, and some of them mentioned at the conference were  $^7\text{Be}(p,\gamma)$ ,  $^{14}\text{N}(p,\gamma)$ ,  $^{18}\text{F}(p,\alpha)$ ,  $^{22}\text{Na}(p,\gamma)$ , and so on. Also, many new important results concerning the masses of the rp-process waiting-point nuclei were presented. The masses of  $^{68}\text{Se}$  and  $^{72}\text{Kr}$  have been measured accurately at the Canadian Penning Trap and ISOLTRAP, as reported by Jason Clark and Frank Herfurth, respectively. Also, very detailed reviews on the r-process, both for experimental and theoretical aspects, were provided by Hendrik Schatz, Karl-Ludwig Kratz, as well as by Stephane Goriely and Gabriel Martinez-Pinedo.

## 10 Fundamental Symmetries

Klaus Jungmann provided us with a highly interesting tour through the different possibilities we have concerning studies of fundamental symmetries and interactions at the current nuclear physics facilities and accelerators. A few of these subjects were specifically presented at the conference: T and CP violation was discussed by Jonathan Engel, correlations in beta decays by John Behr, and the unitarity of the CKM matrix by John Hardy. These experiments are all very difficult and not many of us are involved. However, they are important experiments and definitely should be very strongly supported at our facilities.

## 11 Radioactive Ion Beams and Applications

Production methods and technologies for radioactive ion beams have advanced tremendously, leading to the success of many of the experiments presented at this conference.

This subject was not reviewed at this conference. However, a few important new developments were presented. Piet Van Duppen, from Leuven, reviewed the current status and future developments of laser ion source technology for the production of radioactive beams. While in the past only the ISOLDE at CERN and Louvain la Neuve in Belgium were utilizing this technique, it is now becoming more common and several laboratories are adapting to it. Another important general development related to radioactive ion beam manipulation was presented by Guy Savard from Argonne. Applications, in small scale, were presented as well, but although they are important, they are normally not discussed in detail at this conference. In this connection, we enjoyed a presentation by Jose Benlliure on nuclear cross section measurements for transmutation of nuclear waste.

## 12 Conclusion

In summary, this conference has shown that our field is indeed in good shape, and we have a very enthusiastic community. I would like to underline that theoretical efforts have been significant, and they are able to offer challenges for the experiments which I think are particularly important. We are living in exciting times, during which new facilities are developing throughout the whole world. There is great promise for an excellent ENAM 2008 conference in Poland.

Thank you.